A Comparison of Mode S ADS-B Performance in Three LA Basin 2020 Scenarios

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Presentation Outline

- Description of ADS-B
- Description of DAG-TM Concept
- OPNET Modeling Environment
- Simulation Parameters
- Simulation Results
- Discussion

ADS-B Background

- Automatic Dependent Surveillance - Broadcast
- Defined in RTCA DO-242A
- Position, velocity, and status information broadcast from aircraft at regular intervals using information obtained from Global Positioning System (GPS) Satellites and onboard systems
- July 2002 Data Link Decision by FAA
  - High performance and commercial aircraft will use Mode S
  - General aviation will equip with Universal Access Transceiver (UAT)
  - Equipage is optional but equipped aircraft will have the increased situational awareness necessary for Free Flight.

DAG-TM Concept

- Distributed Air/Ground Traffic Management (DAG-TM) is part of the Advanced Air Transportation Technologies (AATT) Project in the NASA Airspace Systems Program.
- Flight crews, air traffic personnel, and airline operational centers will use distributed decision-making to enable user preferences and increase system capacity.
- For the purpose of NASA research into feasibility, DAG-TM has been divided into fifteen concept elements
  - CE-5, CE-6, and CE-11 are currently funded under AATT
  - This presentation focuses on the use of ADS-B in Concept Element 5.

DAG-TM Concept Element 5

- Concept Element 5 is En-route Free Maneuvering for
  - User-preferred Separation Assurance, and
  - User-preferred Local TFM Conformance

- "Appropriately equipped aircraft accept the responsibility to maintain separation from other aircraft, while exercising the authority to freely maneuver in en route airspace in order to establish a new user-preferred trajectory that conforms to any active local traffic flow management (TFM) constraints."

ADS-B Mode S Datalink

- Concept Element 5 of DAG-TM is envisioned to exist in en-route airspace (outside the TRACON).
- Aircraft operating in the DAG-TM Concept of Free Flight will primarily be commercial and high performance GA aircraft
- Mode S technology was developed at MIT Lincoln Labs for use in Secondary Surveillance Radar.
- ADS-B makes use of the data link capabilities in Mode S
- Mode S Documentation
  - RTCA DO-181C
  - RTCA DO-260A (1090 MHz (Mode S) ADS-B and TIS-B)

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DAG-TM Surveillance Environment

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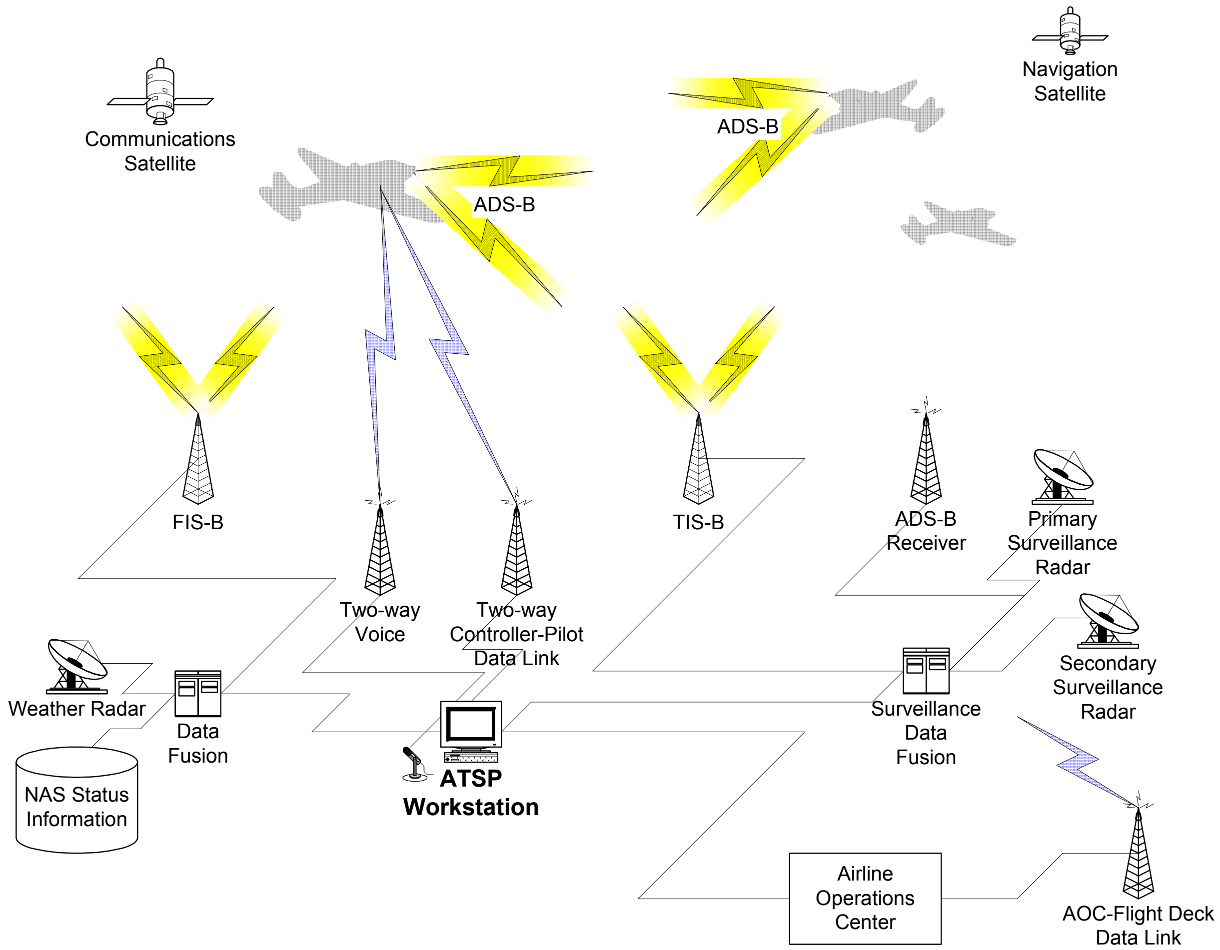

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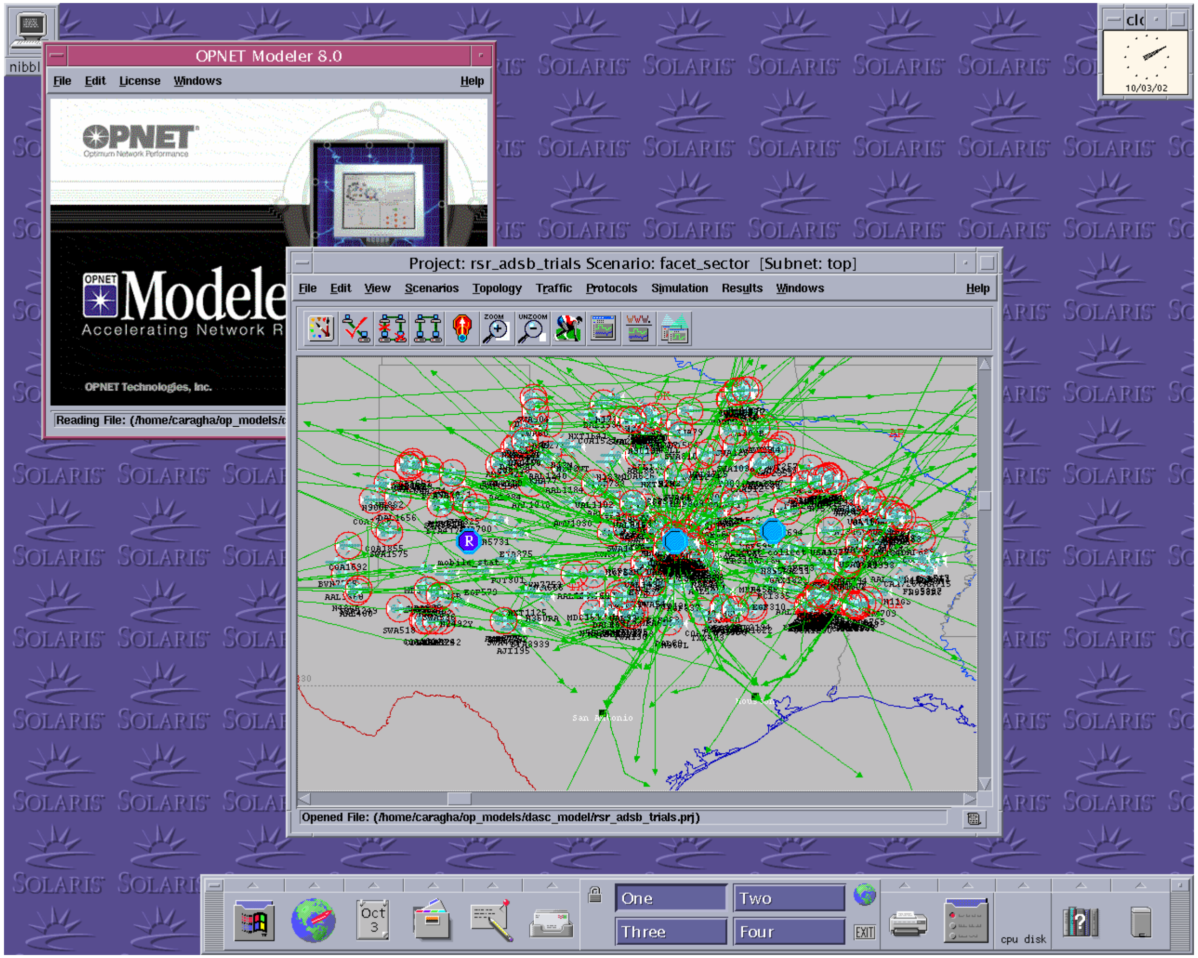
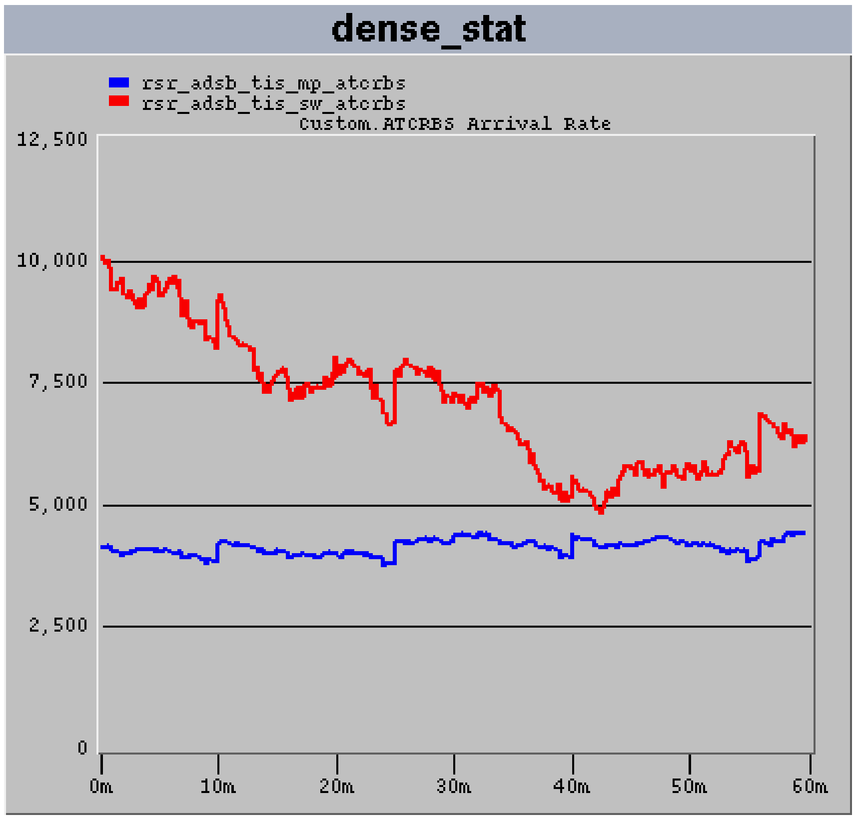
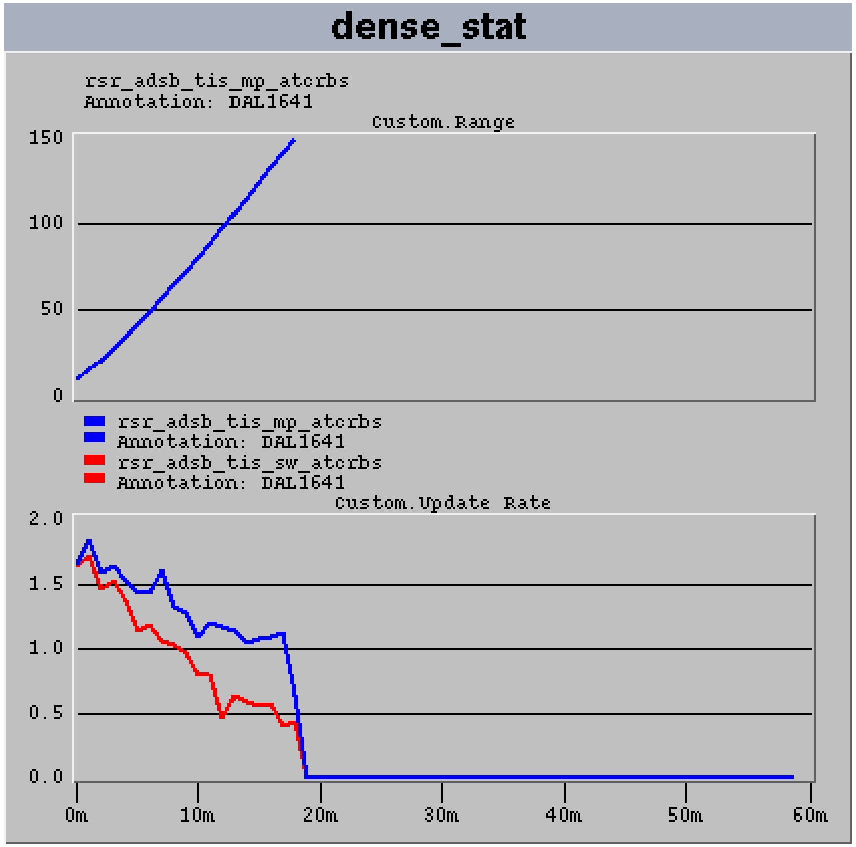
OPNET Modeling Environment

Glenn Research Center



ADS-B reception in ZFW Sector Monopulse vs. Sliding Window ATCRBS





Monopulse vs. Sliding Window ATCRBS

Newer ATCRBS radar systems use monopulse technology

Older ATCRBS systems are of the sliding window format

- **Monopulse ATCRBS**
- 20 ground stations in range
- 4.6 seconds per rotation
- 0.23 seconds per interrogator
- 2.75 degree beamwidth
- 35 msec burst
- 130 msg/sec interrogation rate
- 4.568 msg/burst

- **Sliding Window ATCRBS**
- 20 ground stations
- 4.7 secs/rotation
- .235 seconds/interrogator
- 7.28 degree beamwidth
- 95 msec burst
- 331.5 msg/sec interrogation rate
- 31.5 msg/burst

OPNET Simulation Parameters – LA Basin 2020 Scenarios

- LA Basin 2020 traffic file provided to NASA Glenn by researchers at Johns Hopkins Applied Physics Laboratory; file conforms to ADS-B traffic scenario in RTCA DO-242A
- SSRs assumed to be dual-mode Mode S / Monopulse ATCRBS
- Different classes of aircraft have different transmitter power. There is also a class for ground vehicles. ADS-B message distribution corresponds to RTCA DO-260A (draft).
  - In scenarios with ATCRBS, Class A3 and A2 aircraft transmitted 1090 MHz ES ADS-B and replied to Mode S interrogations. Class A1 and A0 replied to ATCRBS interrogations. In one scenario, replies were relayed as 1090 MHz ES TIS-B by ground stations.
  - In final scenario, 100% of aircraft were Mode S equipped and transmitted ADS-B. No ATCRBS replies. Hence no TIS-B traffic.

OPNET Simulation Parameters – LA Basin 2020 Scenarios (cont.)

- Receiver aircraft collecting statistics had Class A3 MTL for transponder. One stationary at center of LA Basin. Four at NE, NW, SE, and SW corners, converging to center at 450 knots.
- Reply rates to ground-based Mode S and ATCRBS radars determined based on numbers cited in 2000 FAA LA Basin report.
- ADS-B transmissions, Mode S replies, ATCRBS replies, and TCAS signaling were all on 1090 MHz.
- ADS-B messages above Class A3 MTL were successfully received unless interfered with by MORE THAN one other packet within +/- 6 dB during reception.

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LA Basin 2020 Update Rate
Center of LA Basin

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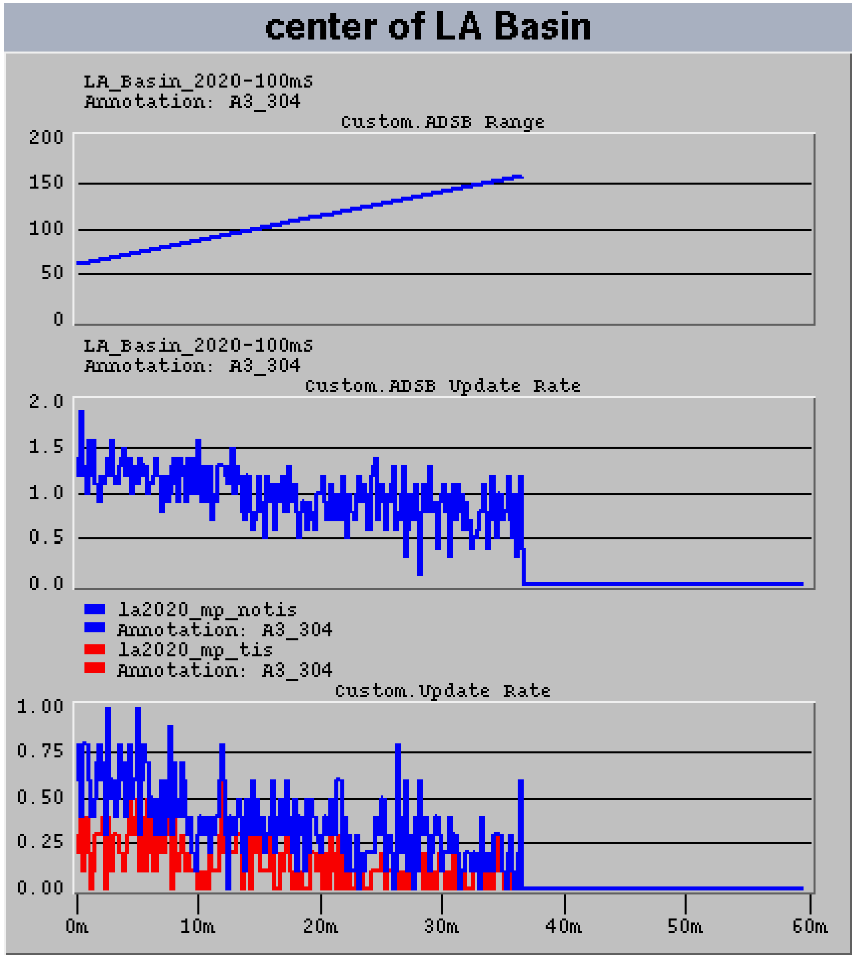

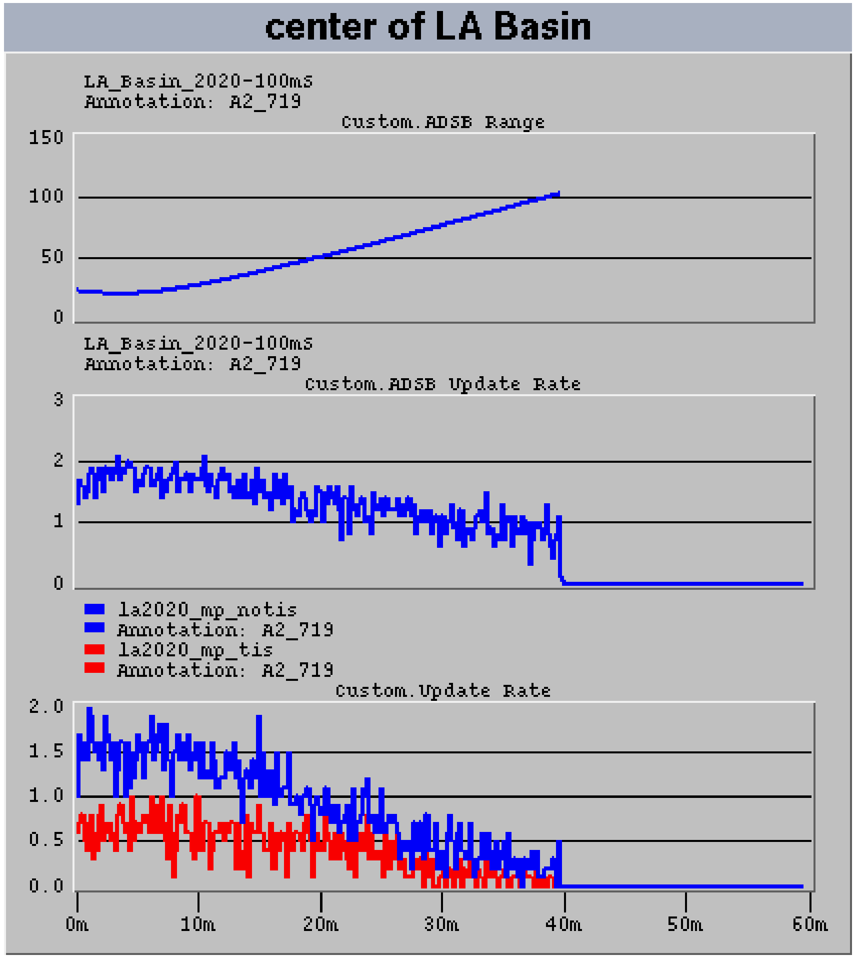

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LA Basin 2020 Update Rate Approaching LA Basin

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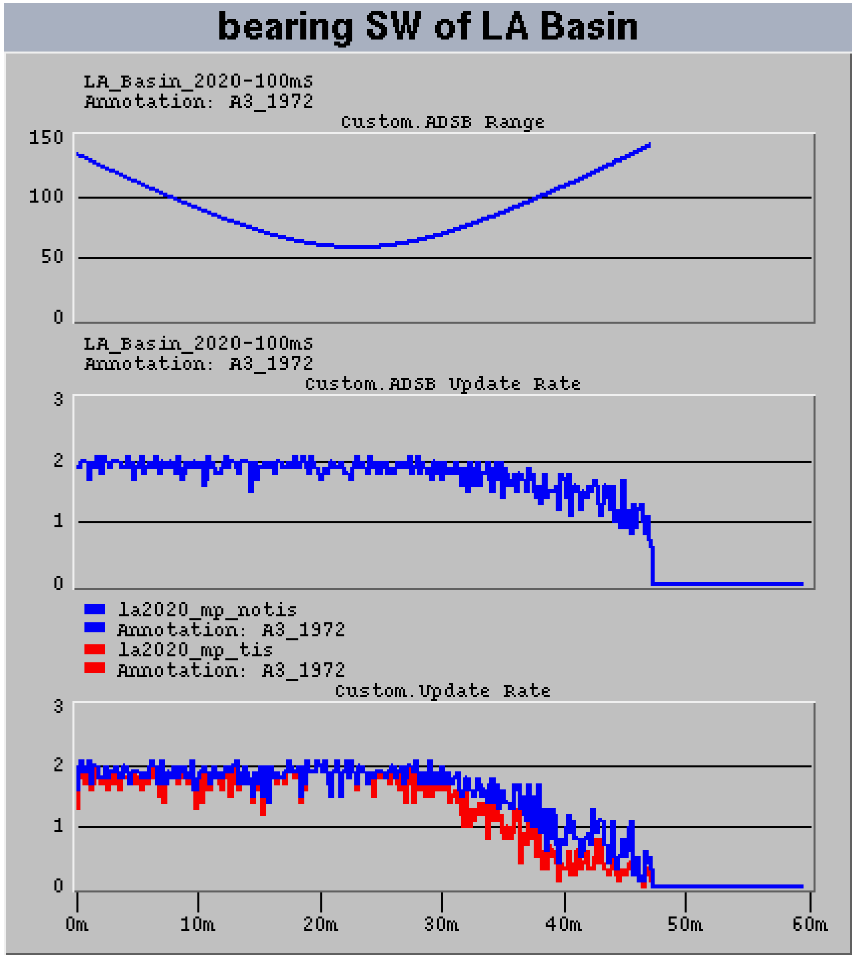
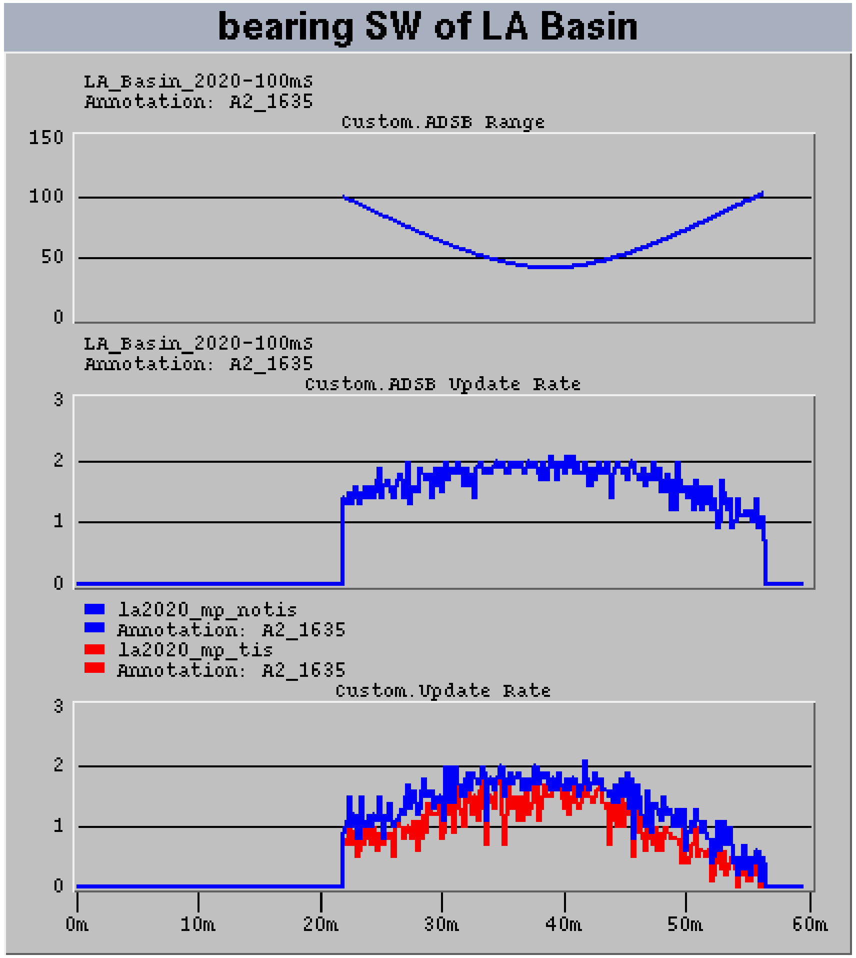
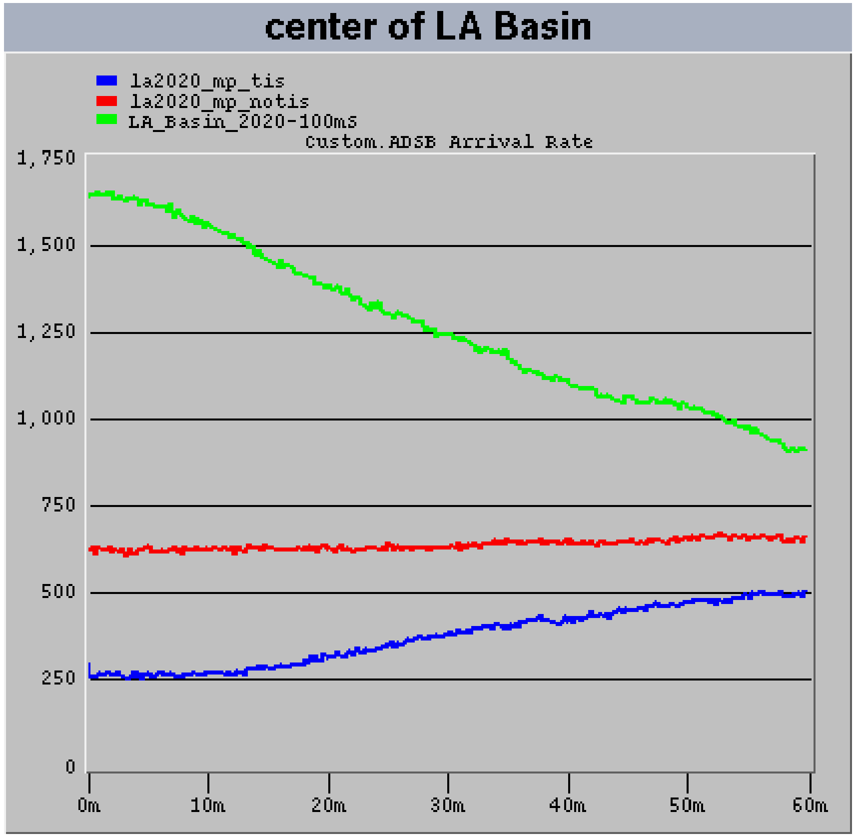
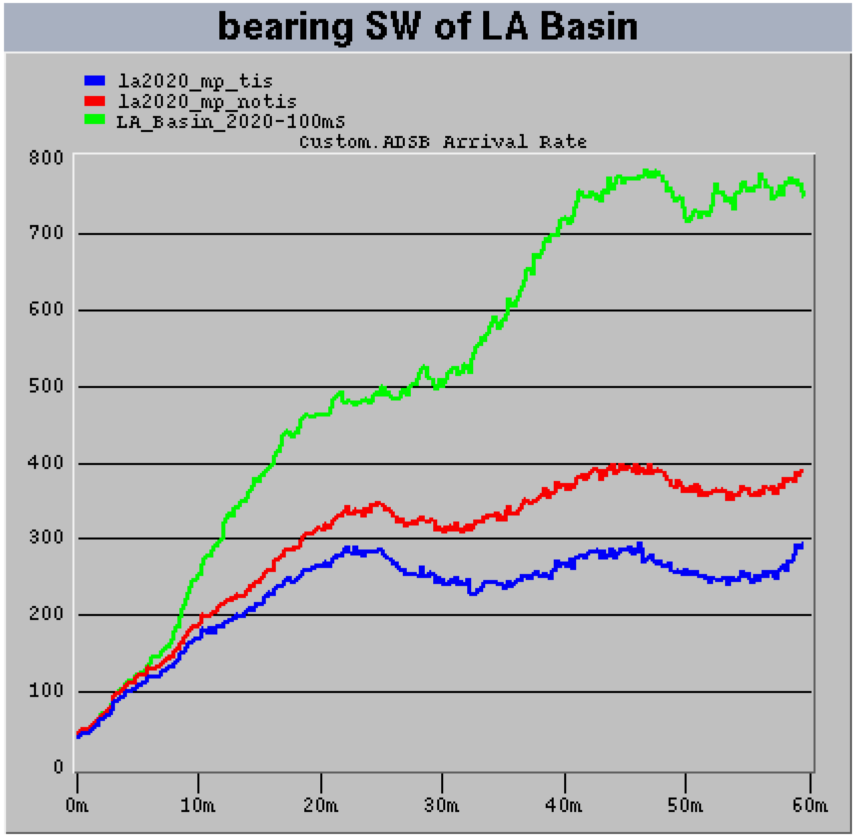


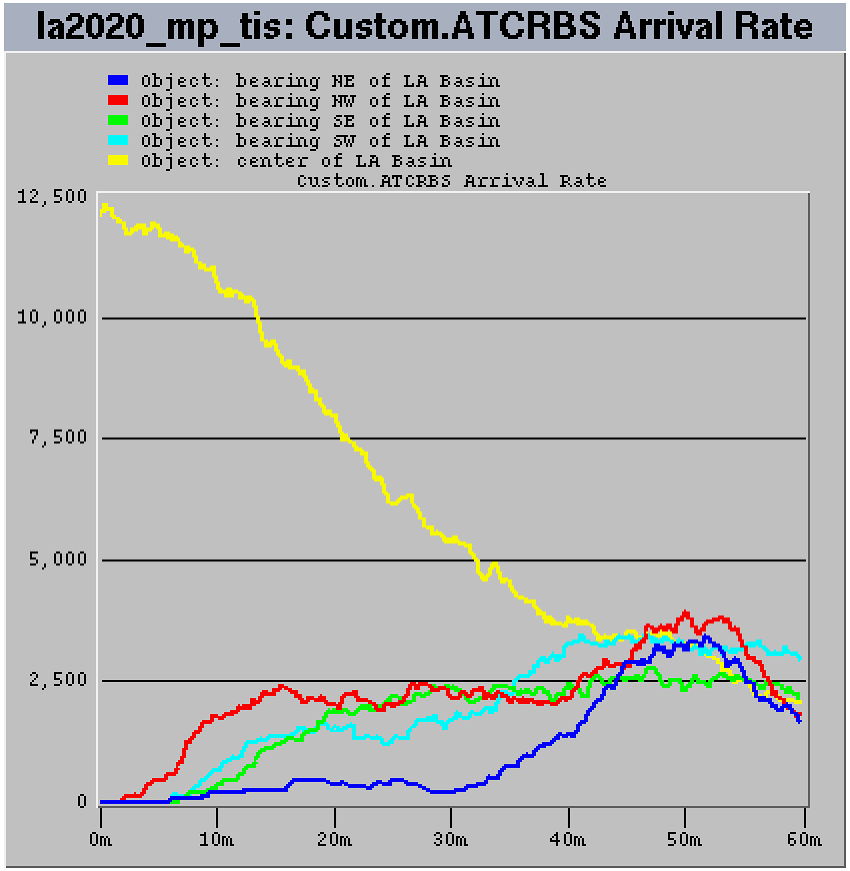


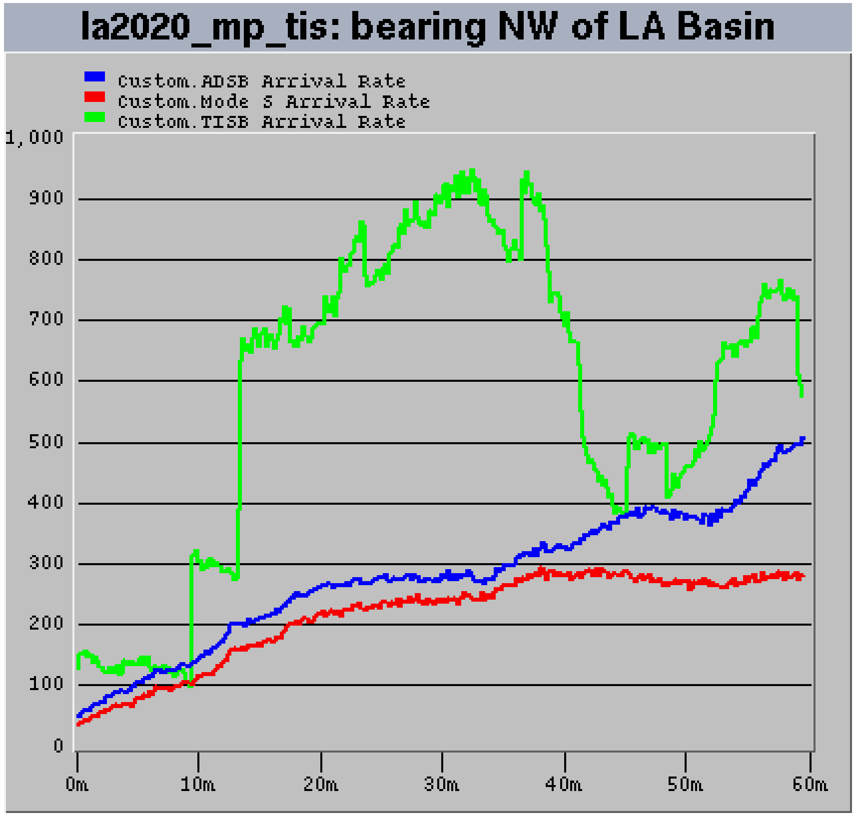
LA Basin 2020 Results
ADS-B Arrival Rates



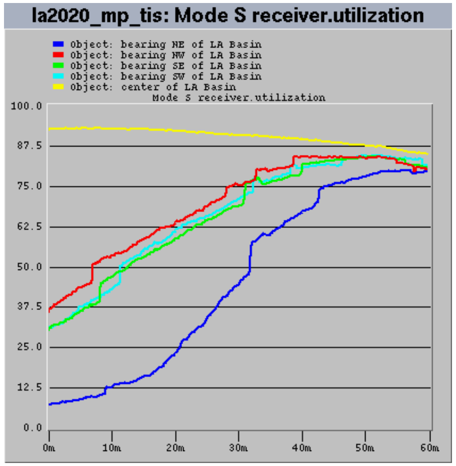


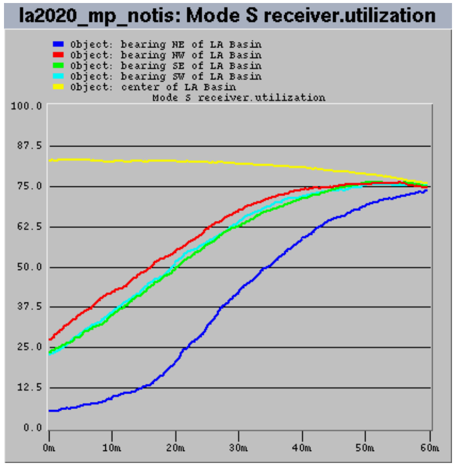
LA Basin 2020 Results
Arrival Rates with ATCRBS

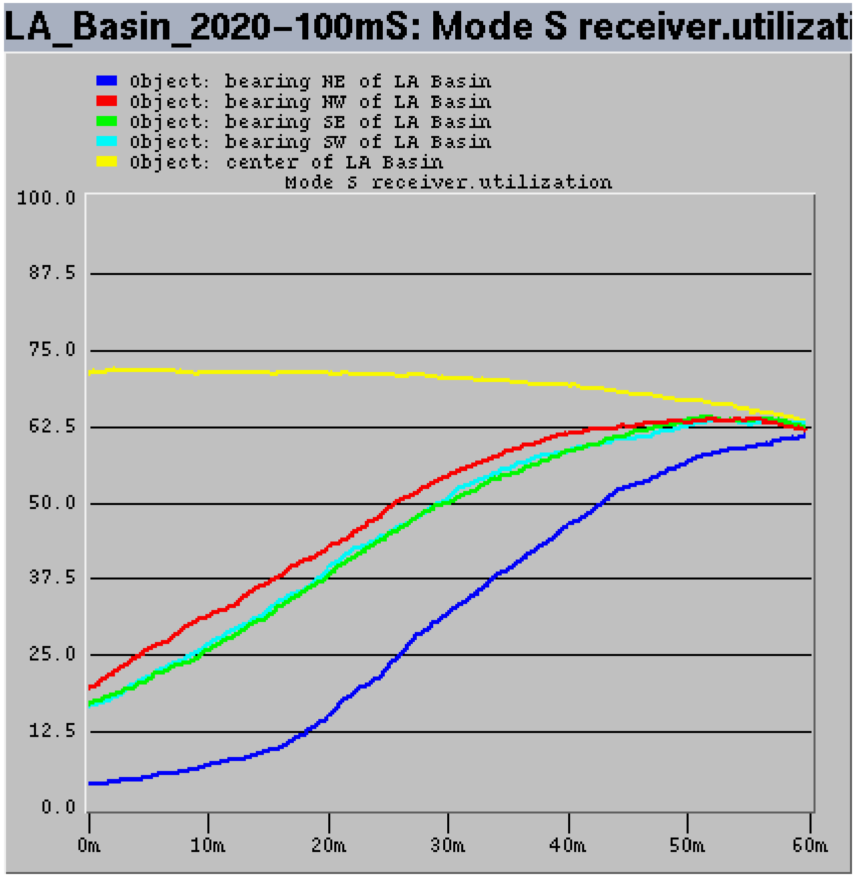




LA Basin 2020 Receiver Utilization







Assumptions and Limitations

- The true interference environment has been observed to be non-Gaussian based on MIT Lincoln Laboratories flight tests in the LA Basin in 1999. The approximation (multiple interferers within +/- 6 dB) was suggested to the author by Jon Bernays of the ATC group at MIT Lincoln Labs.
- The OPNET model used isotropic antennas instead of top/bottom mounted omnidirectional antennas specified in RTCA DO-181C.
- If an aircraft is Mode S capable, the model assumed it would be interrogated as such. In reality older ATCRBS SSRs may interrogate it, increasing the ATCRBS traffic present.
- To improve simulation speed, TCAS interrogations and SSR interrogations were not explicitly modeled. TCAS replies assume a constant maximal interrogation rate, and the nature of SSR interrogations was based on the number of ground sites observed by MIT Lincoln Laboratories in their 1999 LA Basin study.

Assumptions and Limitations (cont.)

- The inclusion of TIS-B in the model was necessarily approximate in nature. The location and placement of actual TIS-B ground stations is still unknown and the TIS-B protocol for transmission rates has not yet been specified by the RTCA.
- Similarly, ground (zero altitude) receivers for ADS-B were not modeled, although they could have been.
- Although there was a transmission delay in addition to the free space propagation delay, and although simultaneous 1090 MHz messages within a node get queued for transmission, the onboard processing delay within the FMS was not modeled, due to a lack of information on how to do so.
- Interference from 1030 MHz transmissions were not included, because based on the OPNET interference model, they would not affect 1090 MHz reception.

Acknowledgments

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Conclusions and Future Directions

- A monopulse ATCRBS environment is necessary for ADS-B to coexist with SSRs.
- The LA Basin 2020 environment strains the performance and capacity of the Mode S ADS-B link, particularly at the center of the region, where traffic is greatest.
- Future studies need to collect statistics on TIS-B to analyze information relayed from primary and secondary surveillance radar in the 1090 MHz environment
- UAT statistics have been collected but not yet analyzed.